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Comparison of the growth of the tunica media of the ascending aorta, aortic isthmus and descending aorta in infants and children

HILDE VAN MEURS-VAN WOEZIK, HANS WERNER KLEIN, LOES MARKUS-SILVIS AND P. KREDIET

Department of Anatomy, Faculty of Medicine, Erasmus University, Rotterdam, P.O. Box 1738, 3000 *DR Rotterdam, The Netherlands*

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INTRODUCTION

Observations on the growth of the descending aorta in normal infants and children, based on measurements of the internal diameter, and comparing it with the internal diameters of the aortic isthmus and ascending aorta, were reported in a previous paper (van Meurs & Krediet, 1982*b*). These three parts of the aorta, the ascending aorta, aortic isthmus and descending aorta, are of different embryological origin, i.e. developing from the saccus aorticus, fourth aortic arch and dorsal aorta, respectively. It is therefore of interest to investigate whether the alterations, during bodily growth, of their internal diameters are accompanied by comparable histological changes in their tunica media. Accordingly, we measured the thickness of the tunica media of the various parts of the aorta, as well as the packing density of the elastic fibres, comparing the findings with the internal diameters. Although there are different methods of calculating the packing density of the elastic fibres of the media of vessels (Hass, 1942; Berry, Looker & Germain, 1972; Mackay, Banks, Sykes & Lee, 1978; Plank, James & Wagenvoort, 1980; Toda *et al.* 1980; Pang & Scott, 1981), we prefer the method of point counting, to be able to compare our calculations on the aortic tunica media with the calculations in previous studies on the great vessels (van Meurs, Klein & Krediet, 1980; van Meurs & Krediet, 1982*a*).

MATERIALS AND METHODS

In post mortem material consisting of 69 hearts and great vessels of infants and children, who died from non-vascular diseases, we examined the tunica media and the internal diameter of the ascending aorta (1–2 cm beyond the valve), the aortic isthmus (between the left subclavian artery and the ductus arteriosus) and the descending aorta (1 cm distal to the ductus arteriosus). The age range was from 27 weeks of gestation up to 10 years after birth. The internal diameters of the different parts of the aorta were measured within 24 hours after death and before fixation, with the aid of calibrated probes, differing 1 mm in diameter. Diameter values of 0·5 mm were ascertained by interpolation. After fixation of the hearts and great vessels with 4 % formaldehyde solution, transverse rings were taken out of the ascending aorta, aortic isthmus and descending aorta. After embedding the rings in paraffin, without distention 7 μm transverse sections were stained with haematoxylin and eosin, or with Weigert's fuchsin-resorcin. The mean thickness of the tunica media

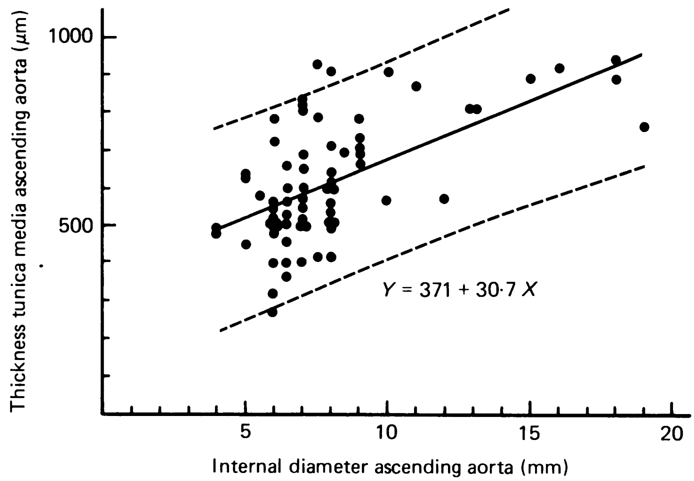


Fig. 1. Correlation between thickness of tunica media and internal diameter of ascending aorta in 69 normal hearts; interrupted lines indicate '95 %' limits for the data.

was calculated from 20 determinations equally distributed over the circumference of the vessel. The packing density of the elastic fibres of the tunica media, i.e. the percentage of the cross sectional area of the tunica media occupied by elastic fibres, was calculated as the mean of 20 determinations by the method of point counting described by Weibel & Elias (1967). This method and its reliability were described in a previous paper (van Meurs *et al.* 1980). Correlations were calculated following Sachs (1973). Using Student's *t*-test, a difference was considered significant if the two-tailed probability was $\leqslant 0{\cdot}05$.

OBSERVATIONS

The data obtained on the thickness of the tunica media and the packing density of its elastic fibres in ascending aorta, aortic isthmus and descending aorta were plotted against the internal diameter of the corresponding part of the aorta.

The thickness of the tunica media of the ascending aorta, aortic isthmus and descending aorta showed a distinct correlation with the internal diameter (Figs. 1, 3, 5). The approximately fourfold increase of the internal diameter (from about 4 to 15 mm) was accompanied by a parallel, approximately twofold increase of the thickness of the tunica media of these three parts of the aorta (from about 450 to about 800 μm). The relationship between internal diameter and thickness was not significantly different for the three parts of the aorta. This is shown by the '95 % limits', indicated in Figures 1, 3 and 5.

The packing density of the elastic fibres of the tunica media of the ascending aorta showed a distinct correlation with the internal diameter (Fig. 2). The fivefold increase of the internal diameter of the ascending aorta (from 4 to 20 mm) was accompanied by a parallel increase of the packing density of the elastic fibres of the tunica media, from about 16 to 38 %.

In contrast with the conditions found in the ascending aorta, the values for the packing density of the elastic fibres of the tunica media of the aortic isthmus and of the descending aorta showed no marked increase in parallel with the internal diameter

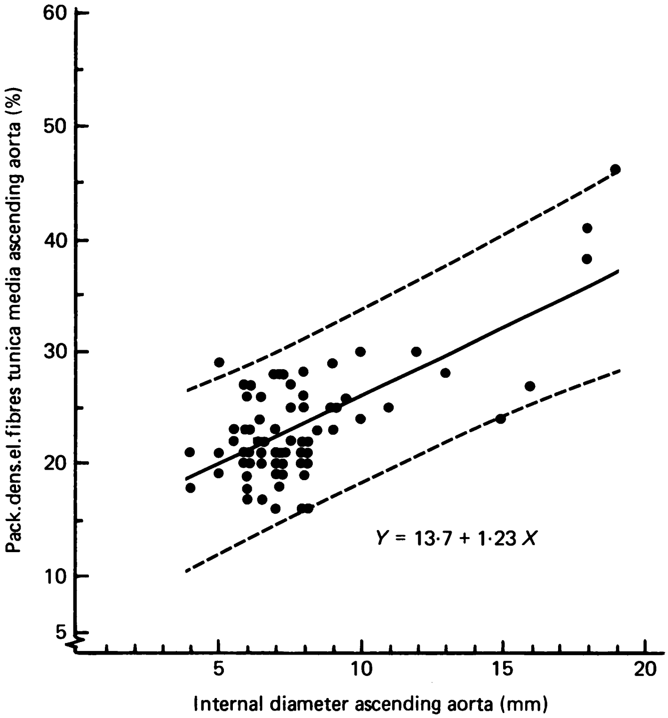


Fig. 2. Correlation between packing density of elastic fibres of tunica media and internal diameter of ascending aorta in 69 normal hearts; interrupted lines indicate '95 % limits' for the data.

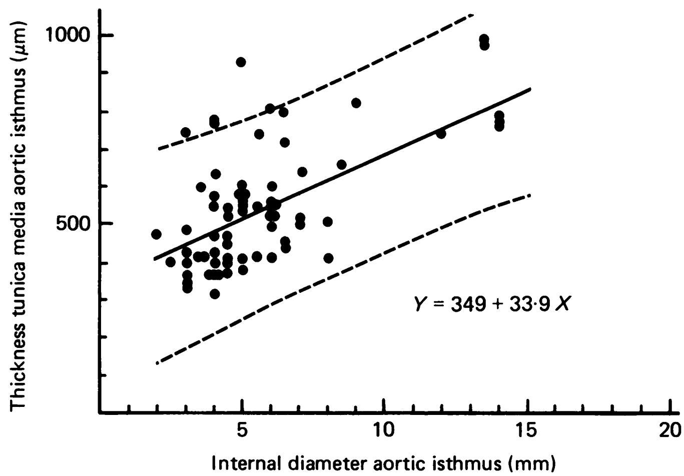


Fig. 3. Correlation between thickness of tunica media and internal diameter of aortic isthmus in 69 normal hearts; interrupted lines indicate '95 % limits' for the data.

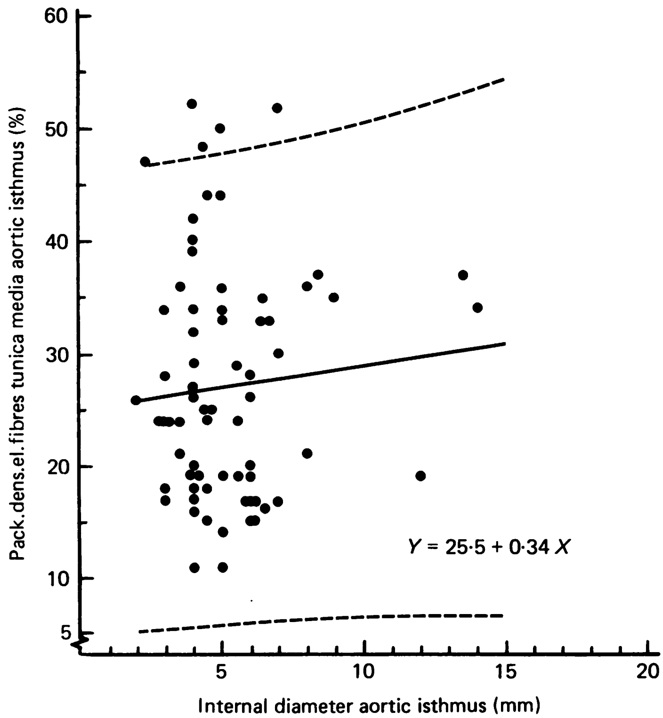


Fig. 4. Correlation between packing density of elastic fibres of tunica media of aortic isthmus in 69 normal hearts; interrupted lines indicate '95 % limits' for the data.

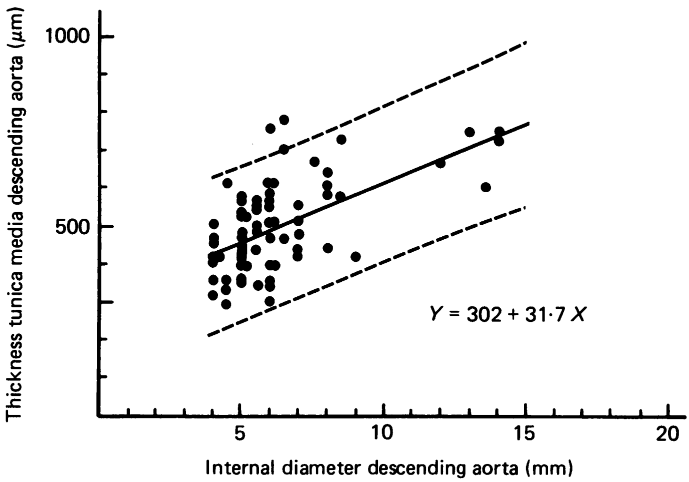


Fig. 5. Correlation between thickness of tunica media and internal diameter of descending aorta in 69 normal hearts; interrupted lines indicate '95 % limits' for the data.

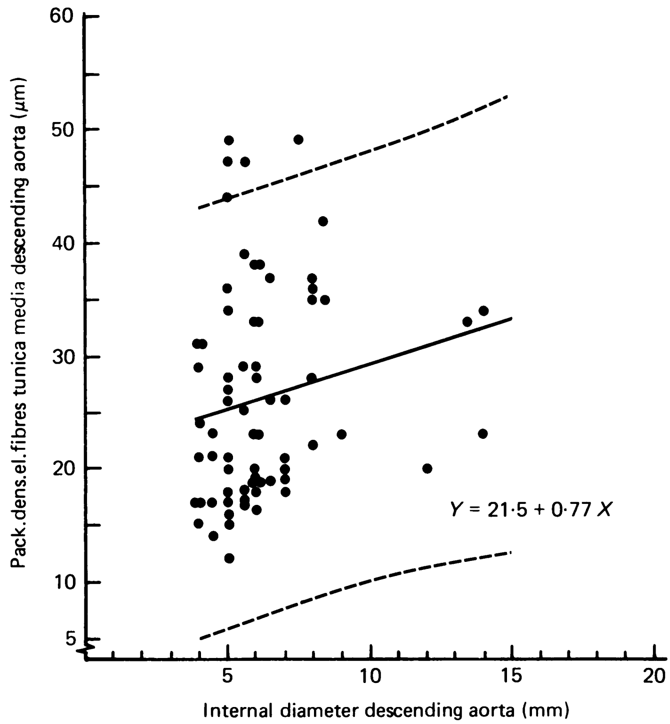


Fig. 6. Correlation between packing density of elastic fibres of tunica media of descending aorta in 69 normal infants; interrupted lines indicate '95 % limits' for the data.

(Figs. 4, 6). The approximately fivefold increase of the internal diameter of the aortic isthmus and descending aorta (from about 3 to 15 mm) was accompanied by a parallel increase of the packing density of the elastic fibres of the tunica media (from about 25 to only about 33 %). However, as shown by the '95 % limits', the packing density of the elastic fibres showed large variations for both these parts of the aorta. The general histological appearance of the elastic fibres was the same in all three parts of the aorta studied.

DISCUSSION

To investigate the normal structural growth of those parts of the aortic arch which are of different embryological origin, i.e. the ascending aorta (saccus aorticus), aortic isthmus (fourth aortic arch) and descending aorta (dorsal aorta), we determined the internal diameters of these parts of the aorta as well as the thickness of their tunica media and the packing density of the elastic fibres. In a previous paper (van Meurs & Krediet, 1982*a*), linear correlations were found between, on the one hand, the internal diameters of these different parts of the aorta and, on the other hand, body length up to 140 cm. In agreement with Heath, Wood, DuShane & Edwards (1959) we found in this study an approximately twofold increase of the thickness of the tunica media of the ascending aorta parallelling a fourfold increase in internal diameter (Figs. 1, 7A–D). Similar values were found for the aortic isthmus and the descending aorta (Fig. 3, 5, 7B–E, 7C–F).

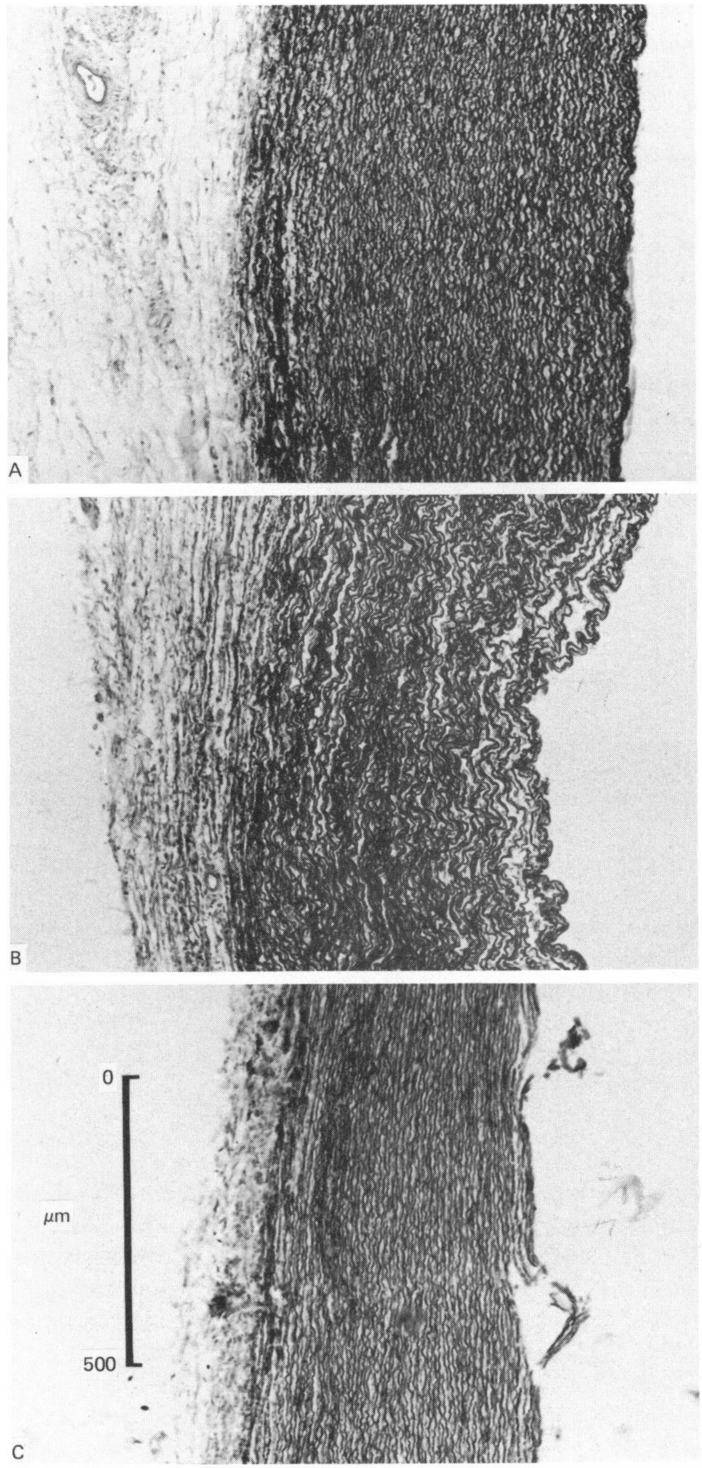
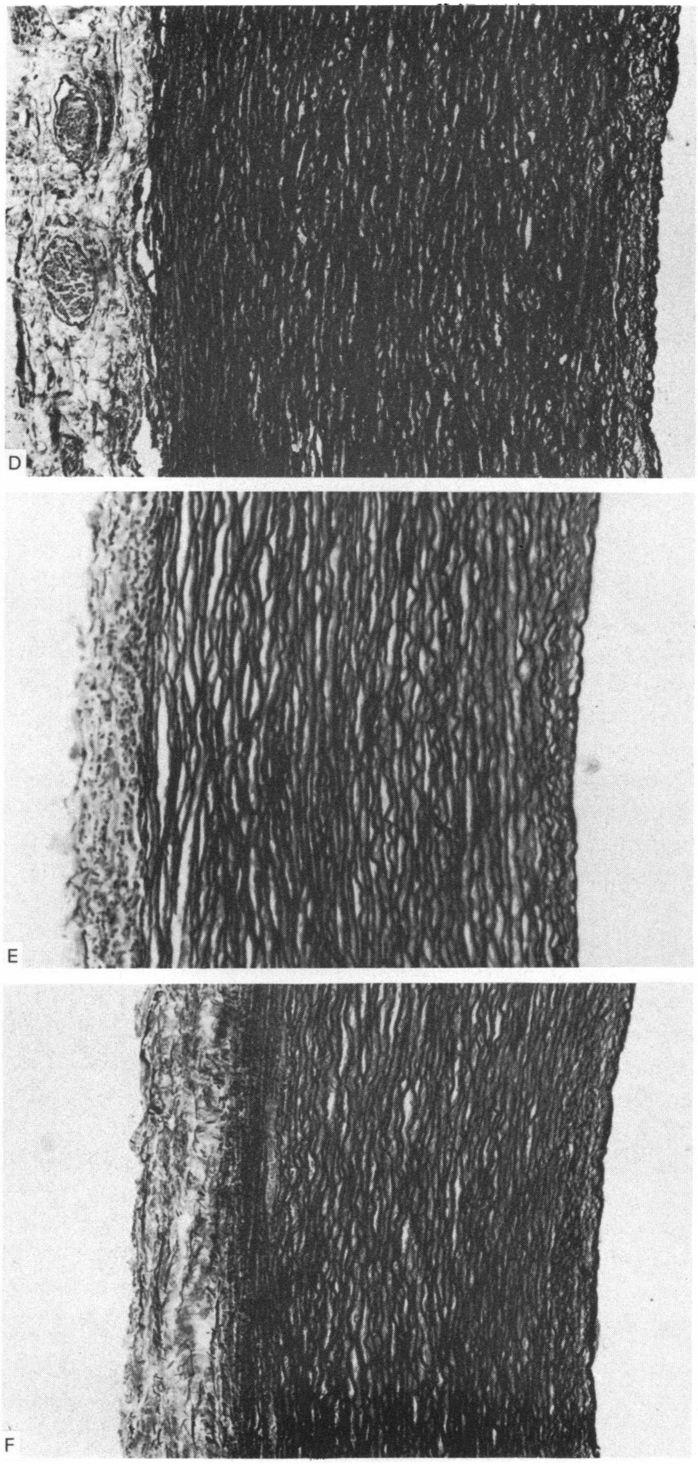


Fig. 7(A–F). Differences in growth of the tunica media of the ascending aorta (AscAo), aortic isthmus (AoI) and descending aorta (DescAo) in two normal hearts with regard to the thickness (Th) of the media and packing density of its elastic fibres (PDEF). D = diameter. All to same magnification. Case 1. Stillborn; length 44 cm. (A) AscAo: D, 6·5 mm; Th, 594 μm;



PDEF, 22%. (B) AoI: D, 4 mm; Th, 549 μm; PDEF, 27%. (C) DescAo: D, 5 mm; Th, 425 μm; PDEF, 17%. Case 2. Age 5 years 8 months; length 123 cm. (D) AscAo: D, 18 mm; Th, 938 μm; PDEF, 41%. (E) AoI: D, 12 mm; Th, 736 μm; PDEF, 19%. (F) DescAo: D, 12 mm; Th, 674 μm; PDEF, 20%.

The following can be said about our observations on the packing density of the elastic fibres of the tunica media of the first parts of the aorta. Only in the tunica media of the ascending aorta did we find a marked increase of the packing density of the elastic fibres in parallel with increasing internal diameters. The approximately five-fold increase of the internal diameter was accompanied by an approximately twofold increase of the packing density of the elastic fibres (Figs. 2, 7A–D). In contrast with the conditions found in the ascending aorta, the packing density of the elastic fibres of the aortic isthmus and of the descending aorta showed no marked increase in parallel with increasing internal diameters (Figs. 4, 6, 7B–E, 7C–F). The structural arrangement of the elastic fibres was the same in all three parts of the aorta studied.

In conclusion we found that, although the first three parts of the aorta, ascending aorta, isthmus and proximal part of descending aorta, are of different embryological origin, at birth the tunica media of these three parts of the aorta are comparable in histological structure. However, during the bodily growth of infants and children the tunica media of these parts of the aorta grows differently. Only the former saccus aorticus (ascending aorta) shows a marked increase of the thickness of its tunica media as well as of the packing density of its elastic fibres. The former fourth aortic arch (aortic isthmus) shows, like the former dorsal aorta (descending aorta), only a marked growth of the thickness of the tunica media, whilst the packing density of the elastic fibres shows no clear tendency to increase during bodily growth. This is a remarkable growth difference, which cannot be explained by the minimal difference in blood pressure in the three parts of the aorta. It is known that the systemic arteries serve as a pressure reservoir by means of the elastic properties of the walls. The contracting left ventricle rapidly ejects blood into the aorta, which becomes distended as the arterial pressure rises. By this means the ascending aorta functions as a type of surge chamber immediately downstream from the left ventricle (Rushmer, 1972). Therefore, it is more likely that the different growth of the tunica media of the ascending aorta is due to its specific function, working as a surge chamber, than that it occurs as a result of different embryological origin.

The results of this study give some information on the range of normal development. In cases with a coarctation of the aorta (at the site of the ductus arteriosus) the internal diameter of the aortic isthmus often fails to increase after repair of the coarctation by the technique of resection and end-to-end anastomosis. Factors affecting the rate of recurrence of aortic coarctation with end-to-end anastomosis primarily relate to the infant's size and the diameter of the anastomosis (Williams *et al.* 1980). However, Hamilton, Eusanio, Sandrasagra & Donnelly (1978) showed, in a 3–7 years follow-up of aortoplasty with a subclavian flap for coarctation of the aorta, that the reconstructed area had grown in girth and had attained adequate calibre for the age of the child. It would be of interest to study the aortic isthmus in these cases of coarctation of the aorta with regard to the characteristics of its tunica media as a next step to the definition of the border line between normal and pathological conditions.

SUMMARY

This study concerns the normal histological growth of the aorta in infants and children. We measured, in post mortem material consisting of 69 hearts and great vessels of infants and children who died from non-vascular diseases, the internal diameters of the ascending aorta, aortic isthmus and descending aorta together with

the thickness of the tunica media and the packing density of its elastic fibres. Age range was from 27 weeks of gestational age up to 10 years after birth.

The growth of the tunica media of the ascending aorta was, in part, different from that of the aortic isthmus and descending aorta. Notwithstanding an increase in the thickness of the tunica media parallelling, in all three parts of the aorta, an increase in their internal diameters, the packing density of the elastic fibres of the tunica media of the aortic isthmus and of the descending aorta showed no tendency to increase with age. However, the packing density of the elastic fibres of the ascending aorta showed a continuing increase with age parallelling the increase of the internal diameter. This can probably be better explained as a result of functional difference than as a result of different embryological origin.

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